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## (54) A METHOD OF AND APPARATUS FOR EXAMINATION OF OBJECTS

(71) I, GERALD KEITH SKINNER, a British Subject of, The University of Birmingham, Edgbaston, Birmingham 15, in the County of Warwick, do hereby declare the invention for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of and apparatus for automatically examining objects to sense optically presented characteristics and to furnish data as to one or more parameters of such characteristics.

The invention has been developed in relation to a requirement to perform automatically some of the work involved in the examination of cervical smears for women undergoing tests for cancerous or pre-cancerous conditions. Conventional examinations of cervical smears requires a considerable amount of exacting work by a trained cytologist using a microscope to search for subtle changes in a small proportion of the cells present.

Whilst one objective of the present invention is to provide a method and apparatus whereby cytologists may be relieved of part of the examination work, it is to be understood that the invention is not so limited.

When applied to the examination of cervical smears the optically presented characteristics which are required to be examined are the shape and size of cell nuclei. When the smear is stained in accordance with known techniques the cell nuclei appear as dark bodies of generally rounded form usually against a background of cytoplasm which is less densely coloured. Although extremely subtle changes in the appearances of cells must be recognised by a cytologist, a useful preliminary examination may be carried out on the basis of the size of cell nuclei. The objective of the application of this invention in this instance is to detect the presence of cell nuclei larger than a certain size, corresponding approximately to 12 microns minimum diameter.

In order that cell nuclei may be detected information as to the shape of dark bodies present in the specimen is sensed and parameters connected with the size of detected cell nuclei are determined.

The invention may, of course, be applied in other fields to the examination of objects which have optically presented characteristics.

In general the object to be examined may be in the solid state, liquid state, or even gaseous state, or may include components in any two or more of these states.

The characteristic to be examined should be one which causes modulation of a transmitted or reflected ray from a source of radiation. By way of example, such modulation will occur at the boundaries of the object or at the boundaries between portions of an object which have different coefficients of transmission or reflection with respect to the radiation (one of such portions may be a cavity or vacancy). Such portions are herein referred to as "features" of the object. The characteristic which it is required to examine need not necessarily be defined by a boundary. It may be the presence or absence of an object or a feature thereof having a coefficient of transmission or reflection with respect to the radiation above or below a predetermined value.

The data to be determined by examination of the characteristic again may vary. It may comprise the dimension or the number of objects occupying a given space, or features of an object having certain characteristics.

From one aspect the invention comprises a method of examining an object to provide data as to an optically presented characteristic thereof comprising the steps of establishing incidence of rays of radiant energy from at

least three spot areas on the object on respective transducer elements responsive to said rays to produce primary electrical signals, effecting simultaneous relative movement in a first direction between said spot areas and said object in a manner such that said spot areas scan parallel adjacent tracks on said object collectively forming a scanning band, said rays being modulated by visible boundaries on said object between respective areas thereof, and subjecting said primary signals to analysis to determine therefrom dimensions of said respective areas longitudinally of said tracks, and to determine whether said respective areas extend into adjacent ones of said tracks.

The term "optically presented characteristic" is used herein to denote a characteristic which is capable of being detected by modulation of radiant energy. Often the radiant energy will be in the form of visible light rays but in some cases electro-magnetic radiation outside the visible spectrum may be employed, for example infra-red radiation.

By simultaneously scanning the object along a number of parallel tracks, several difficulties associated with other methods are overcome.

Unless only relatively simple characteristics of an object are to be examined it is necessary to compare and correlate signals from different parts of the object. If, as in other methods, all spot areas of the object are scanned serially (that is one after another in succession) it is necessary to effect storage of the signal or of parameters derived from the signal. In the present method such storage is avoided or minimised because signals from adjacent elemental areas are simultaneously available. For example as at least three tracks are scanned simultaneously the dimension of an object or of a feature of an object in a direction perpendicular to the direction of the scanning motion may be determined by the number of tracks in which the corresponding signal is detected. Preferably a large number of tracks are scanned simultaneously, e.g. sixteen as hereinafter described.

In most instances the width of band scanned by the number of adjacent tracks will be less than the width of the region to be examined. Repetition of the scanning may be carried out with the band of tracks displaced in a direction perpendicular to the basic scanning motion by an amount less than the width of the band, so that the bands are contiguous or overlap between bands at their lateral boundaries. This may be accomplished by motion of the object to be examined in either a stepwise or a continuous fashion. Similar motion in a direction longitudinal to the scanned band may be effected in order to examine large regions of an object. In this way it can be ensured that all features of an object which are less than a predetermined size, and which present the characteristic to be examined, are wholly scanned by at least one band of tracks. Thus means for analysing the signals need only respond to features of the object wholly covered by one band of tracks. The probabilities of small object features being detected in more than one band, or of much larger object features not being wholly contained within any band, are calculable and suitable allowances may be made in the interpretation of results obtained by this method. The number of tracks simultaneously scanned to form one band and the degree of overlap between bands can be optimised for each application.

The present method also has advantages in applications where the signal levels are low as, for example, in cases where high optical magnification or infra-red radiation is employed, or where rapid examination is required. If a particular region or object is to be scanned in a specified time, the use of a number of transducer elements allow the necessary frequency bandwidth of each transducer element to be considerably reduced compared with that necessary if a single transducer were to scan the area in the specified time, and the rate of movement required to be generated by the scanning mechanism is smaller.

According to a further aspect of the invention there is provided apparatus for the examination of an object to provide data as to an optically presented characteristic thereof, comprising means for providing a source of radiant energy for illuminating said object, transducer means including at least three transducer elements responsive to radiation from said source to produce respective primary electrical signals, scanning means including firstly optical means for establishing incidence on said transducer elements of rays of said radiation from respective spot areas on said object, and means for causing said spot areas to travel relatively to said object concurrently along adjacent parallel scanning tracks collectively forming a scanning band, said rays being modulated by visible boundaries on said object between respective areas thereof, and electric circuit means for analysing said primary signals to determine therefrom data as to dimensions of said respective areas longitudinally of said tracks and whether said respective areas extend into adjacent ones of said tracks.

The apparatus may include adjustable focusing means for focusing said rays on said respective transducer elements, focusing control transducer elements, optical defocusing means interposed in the path of rays from said area to said focusing control transducer elements respectively and providing for a predetermined degree of defocusing in opposite senses with respect to a properly focused condition, focusing control circuit means operatively connected to said focusing control transducer elements and providing an output signal representative of departure, if any, from said pre-

determined degree of defocusing, and actuating means for operating said adjustable focusing means in response to said output signal to set said adjustable focusing means in a condition properly to focus said image.

Further features of the method and apparatus in accordance with the invention will be apparent from, or will be specifically pointed out in, the following description of a preferred manner of carrying out the method and a preferred embodiment of apparatus in accordance therewith shown in the accompanying drawings, by way of example, in which:—

Figure 1 is a diagram illustrating successive steps in the scanning of an object by the method of the invention;

Figure 2 is a perspective view in somewhat diagrammatic form of one embodiment of the apparatus in accordance with the invention for performing the method thereof;

Figure 3 is a view in side elevation showing constructional features of the apparatus of Figure 2;

Figure 4 is a plan view in somewhat diagrammatic form illustrating the provision of optical means for effecting automatic focusing of the microscope embodied in the apparatus of Figures 2 and 3;

Figure 5 illustrates a modification of the means shown in Figure 4;

Figure 6 is a schematic circuit diagram illustrating one form of means for analysing the primary electrical signal furnished from the apparatus of Figures 2 and 3; and

Figure 7 is a schematic circuit diagram of one of the individual circuit blocks of Figure 6.

Referring firstly to Figure 1, the object to be examined is represented by the rectangle 1 and is assumed to have a planar surface which will modulate transmitted or reflected light rays. It is, however, to be understood that the object 1 may be of any shape and the surface may likewise be of any form, and the radiation selected to be incident thereon would be appropriate to undergo modulation by the particular characteristics which it is required to examine.

Scanning of the object 1 is effected by sequentially scanning frame areas or bands, one of which is represented by the rectangle 2. Conveniently the object is illuminated over the frame area 2 and rays from respective spot areas within the area 2 are transmitted to be incident on respective transducer elements as more fully described hereafter, so that a primary electrical signal is generated by each transducer element representative of the intensity of the light incident thereon from its respective spot area.

Conveniently the spot areas form a row indicated at 3 in which the spot areas are contiguous with each other, but it will be understood that the spot areas could occupy positions which are staggered transversely to the row 3 (thereby admitting of overlap between the spot areas in the direction in which they are moved collectively to effect scanning).

The spot areas forming the row 3 are moved in the direction of the arrow 4 relatively to the object 1 to traverse the frame area 3 from its lower boundary to its upper boundary, as seen in Figure 1. Either continuously during this scanning movement or intermittently on completion of each such cycle of scanning movement, relative movement between the object 1 and the frame area 2 is effected in a direction laterally of the frame area 2. Figure 1 illustrates the case where such lateral movement is continuous and it will be noted that the frame area 2 in section *b* of Figure 1 has shifted to the right as the spot area row 3 has shifted upwardly. Section *c* of Figure 1 represents the beginning of the next scanning cycle of the spot area row 3 where it will be observed that the frame 2 is overlapped laterally with its former position, typically as seen in section *a*, by a distance equal to one half the width of the frame area.

Since the length of the frame area is in general less than the width of the object 1, it will be necessary to conduct examination thereof successively along a plurality of zones indicated at 1*a*, 1*b*, 1*c*, 1*d*. The frame area 2 will be shifted to occupy the zone 1*d* when the zone 1*c* has been completely scanned, that is to say when the frame area 2 has arrived at the right-hand terminal position in zone 1*c*. As shown, the zones are contiguous with each other along their lateral boundaries but they may overlap if desired to some extent, such overlap would be produced by shifting the frame area 2 downwardly by a distance which is somewhat less than the length of the frame area measured vertically as seen in Figure 1.

It will be further noted that, although it is convenient for the spot areas 3 to be contiguous with each other and to form a row, it is not essential that this arrangement be adopted. The spot areas may be staggered or offset relatively to each other in a direction longitudinally of the frame area 2. Such an arrangement would admit of lateral overlap between the scanning tracks covered by the spot areas individually.

An apparatus for carrying out examination of an object in accordance with the scanning procedure illustrated in Figure 1 is shown in Figures 2 and 3 to which reference is now made.

The apparatus comprises the following main parts, a microscope of which the objective and the eyepiece lens unit is shown diagrammatically at 10, a rotating polygonal mirror drum 11, an illumination system 12 for illuminating the object under examination (for example, a specimen mounted on a microscope slide 13), transducer elements in the form of photomultipliers P1 to P16, and means such as the

fibre optic devices shown at F1 to F16 for directing light onto the photomultipliers.

The unit 10 is movable vertically for focusing by a reversible electric motor 54 driving a pinion 55 meshing with a rack 56 on the unit 10.

The slide 13 is typically an elongated rectangle of glass and is to be considered as equivalent to the rectangle 1 in Figure 1. The frame area which can be scanned in a single cycle is much smaller than the part of the slide to be examined and is indicated typically as a small area 16, equivalent to the frame area 2 of Figure 1, having dimension X extending longitudinally of the direction of scan and a dimension Y at right angles to the direction of scan. The frame area is slightly curved due to the mode of action of the scanning means employed, namely the mirror drum 11.

The optical system for effecting illumination of the object provides intense illumination over an area a little greater than the frame area 16. The source of illumination is a filament lamp 17, preferably of a tungsten halogen type, with a closely coiled helical filament arranged with its axis extending parallel to the dimension X. The optical system includes a cylindrical lens 18, a convex lens 19, and associated field stop 20, with aperture 21 defining the longitudinal boundaries of the frame area 16, and a convex condensing lens 22 and an aperture stop 23 with aperture 24.

The microscope 10 is of conventional design. The magnification may be selected in relation to the size of the features of the object to be examined. For examination of cervical smears a linear magnification of 1000 is considered suitable, and includes a table or support for the slide 13 providing for translational movement of the slide in two mutually perpendicular directions respectively parallel to the dimensions X and Y, as indicated by the arrows 25 and 26.

The table 5 is moved in the X direction by a lead screw 6 cooperating with a nut 6*a* on the table 5 and driven by a stepping motor 7 through the intermediary of a reduction gear 7*a*, all carried on a support 8. The support 8 in turn is moved in the Y direction by a lead screw 9 cooperating with a nut 9*a* and driven from a stepping motor 36 through the intermediary of a reduction gear 36*a* having input and output elements rotating about axes at right angles to each other. The microscope, mirror drum and illumination system are all supported by a structure 38 including a base 39 carrying a housing 40 for the illumination system, and arms 41 and 41*a* for supporting the microscope table 5 and its traversing means and the eyepiece and objective lens assembly respectively.

An arm 42 serves to support the mirror drum 11 and a drive motor 43 therefor attached to a plate 44 carried by the arm 42 through the intermediary of antivibration mountings 45 of rubber or like resilient material.

The mirror drum 11 may be of tarnish-resistant steel and has plane mirror facets 27 which may be aluminised to give high reflectivity. The angles of the mirror facets relative to the axis of rotation of the mirror must be sufficiently accurate that the same region of the object plane of the microscope is scanned by the passage of each facet through the operative position indicated at 28.

The mirror drum 11 is carefully balanced rotationally and is rotated at high speed, typically 12000 r.p.m. For this purpose it may be mounted directly on the spindle of a small synchronous motor operated from a high frequency supply, for example a three phase 400 Hz supply which may be generated by a transistorised oscillator unit.

The microscope is adjusted so that light reflected from the mirror facet at the operative position 28 forms a real image of the frame area 16 in the plane represented diagrammatically by the rectangle 29, such image being represented by the broken line boundary 34.

Light from sixteen small square regions E1—E16 constituting optical apertures of the image plane 29, arranged in a row, is passed to respective photomultipliers of the array of photomultipliers P1—P16 by the fibre optic devices F1—F16. The ends of the fibre optic devices F1—F16 which end (and define) the image plane 29 constitute apertures on which images of the spot areas within the frame area 16 are incident. The uppermost and lowermost of the apertures afforded respectively by fibre optic devices F1 and F16 define the lateral boundaries of the frame area 16 since rays transmitted by the mirror drum 11 to the plane 29 above and below the boundary 34 will not be effective to be transmitted to and to stimulate any of the photomultipliers P1—P16. Light from two further regions S1 and S2 of the plane 29 is conducted to respective photomultipliers P17 and P18 by fibre optic devices F17 and F18.

As the mirror drum rotates in the direction of the arrow 30 an image 34 of the frame area 16 moves across the plane 29 in a horizontal direction as indicated by the arrow 35. Light from a given region of the image thus falls successively on the photomultipliers associated with S1, S2 and one of the areas E1—E16. In effect, therefore, the photomultipliers P1—P16 may be regarded as receiving light from sixteen respective square spot areas that scan the area 16 along parallel tracks in the direction of the dimension X. Photomultipliers P17 and P18 similarly receive light from two respective slit-like areas which scan along the band scanned by the sixteen square spot areas in advance of these.

Fibre optic devices need not necessarily be

used to pass light from the spot areas and slit areas imaged in plane 29 to the respective photomultipliers, but any equivalent means might be used. Thus, for example, in a system providing an alternative to the use of fibre optic devices a cylindrical mirror is placed in the position of areas E1—E16 to reflect light incident on these areas. Light from the areas E1—E16 individually is then focused by sixteen cylindrical lenses onto respective photomultipliers.

Light from the areas E1—E16 incident on respective photomultipliers P1—P16, by whatever means, produces electrical signals which are a function of the particular distribution of dark and light sub-areas along the corresponding scanning tracks of frame area 16.

Collectively, therefore, the output signals from all the photomultipliers P1—P16 provide data as to the characteristics or features of the object within the area 16. In the particular example now described, wherein the object to be examined is a slide containing a cervical smear, the signals provide data permitting the number and size of cell nuclei present within the area 16 to be determined.

The signals can be handled in a number of different ways electronically to provide the desired information. The simultaneous availability of the signals from each of the photomultipliers, however, enables comparisons to be made between the signals derived from adjacent scanning tracks without the necessity for storing such signals.

The signals from photomultipliers P17, or that from P18, or both, may be connected to a circuit to provide a reference signal representative of the average intensity of illumination of the frame area 16 or of part of that area in the region currently being scanned by the areas E1—E16. In particular, having regard to the positioning of S1 and S2 on the approach side of the row of areas E1—E16 such a reference signal may be made to depend partially on the intensity of light at positions in the image 34 before those positions have been scanned by E1—E16. The signals from photomultipliers P17 and P18 may also be used to sense the edges of the scanned image 34, and control the stepping motors and/or the operation of the circuits for processing the primary electrical signals.

As seen particularly in Figure 4, an optional feature of the apparatus is the provision of means for automatically bringing the image in the plane 29 to correct focus.

It will be understood that the eyepiece and objective lens system 10 of the microscope includes means for adjusting the focus, preferably by operation of a reversible electric drive motor.

As seen in Figure 4, two further transducer elements in the form of photomultipliers P20, P21 are provided in association with which are reflector elements 46 and 47 such as beam splitting prisms with partially silvered surfaces which will transmit some rays to the image plane 29 and reflect others through the intermediary of a convex lens 48 and concave lens 49 to the photomultipliers P20 and P21 respectively. Screens 50 and 51 having apertures 52 and 53 respectively control the light area incident in each case at photomultipliers P20 and P21. The path of light rays is indicated diagrammatically in Figure 4 by full lines and the focusing adjustment means of the microscope is correctly adjusted to provide correct or true focus in the image plane 29. Broken lines indicate the path of the light rays for an incorrect or defocussed condition with respect to the image plane 29.

It will be noted that the lenses 48 and 49 provide defocusing to a predetermined degree and in an opposite sense with respect to images formed in the planes 50 and 51.

Accordingly under true focus conditions with respect to the plane 29, the boundaries of images formed in planes 50 and 51 should be blurred to equal extents. The focusing control signals furnished from the photomultipliers P20 and P21 will have identical, or nearly identical, frequency components and a parameter may be derived therefrom representative of the sharpness of the images in planes 50 and 51 such, for example, as the amplitude of a selected frequency component.

The outputs from the photomultipliers P20 and P21 are fed through respective frequency selective amplifiers 57 and 58 having like characteristics and through respective diode and smoothing circuits 59 and 60 also having like characteristics to a comparator circuit such as a differential amplifier 61.

The output from the amplifier 61 is connected to, and serves to energise, the focus control motor 54. The frequency selective amplifiers 57 and 58 may be designed to amplify a band of frequencies produced by scanning of the "nearly in focus" image.

The table or support on which the object is mounted may be movable continuously in the direction of the arrow 26 at a speed such that for the passage of each successive facet 27, through the operative position 28, the frame area 16 will have advanced in the direction Y along the object by a predetermined proportion of the dimension Y relative to the object. The predetermined proportion may be about one half or any other proportion calculated to give the degree of overlap between successively scanned frame areas necessary to give the desired probability that a feature of the object of a given size shall be wholly contained in the area 16 on at least one scan.

On completion of a traverse of the region to be examined in the direction 26, the table or support may be moved incrementally in the direction parallel to the dimension X as indicated by arrow 25. At the same time the

sense of movement parallel to the dimension Y may be reversed.

If desired the incremental step could provide some degree of overlap with respect to the previously scanned strip.

Referring now to Figures 5 and 6, there is illustrated therein a means for analysing the signals. In this case the analysis consists of detecting well spaced features of an object.

In Figure 6 is shown a schematic circuit diagram incorporating seven of the data handling channels. It will be understood that there are as many data handling channels as there are transducer elements such as the photomultipliers P1—P16, the reduced number being shown for simplicity. The channels shown are numbered (n−1) to (n+5) and are shown as receiving signals derived from respectively associated photomultipliers in the series P1—P16. These signals are derived from the primary signals by comparing the latter in circuits represented by block 62 with a threshold voltage at regular intervals to generate pulses.

The pulses occur in groups whenever a spot area scans longitudinally past a feature of the object to be detected. The number of pulses contained in a group is representative of the longitudinal dimension of the feature. Thus it will be noted that channels (n−1) and (n+5) are associated with photomultipliers which do not receive any stimulation by virtue of their light spots not having intersected with a feature, whereas channels (n) to (n+4) respectively pass signals consisting of one, three, five, three and one pulses.

Each of the channels feeds a block represented at B (n−1) to B (n+5) which accepts the data conveyed by the respective signal fed thereto, and after operating upon same in a manner to be described passes the data to each of the adjacent blocks. Thus block B (n) will pass data to block B (n−1) and also to block B (n+1).

Each block such as B (n) is shown in more detail by way of the schematic circuit diagram of Figure 7. In the block a counter 63 detects the number of pulse groups, within the channel, which are to be treated as "falling within" the defined feature to be detected. For example, the counter may reject pulses above a predetermined threshold value or below a predetermined threshold value as appropriate.

A bistable circuit 64, herein referred to as the join circuit, is placed in the set condition in the block B (n) when the counter 63 in this block and in the block B (n−1) receive pulses simultaneously. This signifies that the two counters 63 contain data associated with the same feature, i.e. that the feature extends into adjacent tracks scanned by the spot areas. The output of the join circuit 64 is used to gate-in data from channel B (n−1) in each of a series of gates 65 to 69. The two sets of data are combined in the block B (n) in circuits 70 (add), 71 (larger), 72 (add one) to derive parameters respectively representing the area A, length L and width W of the feature to be determined. Other parameters representing perimeter, length or degree of skew of the feature, for example, may be derived similarly.

The relevant values of the parameters are those at the outputs such as A, L and W of the processing block associated with the "bottommost" of the channels containing data associated with the feature, after reception of the data resulting from the scanning in all of the channels. This condition is detected by generation of a signal $\overline{E}$ (NOT END) if any of the counters 63 are still receiving data from a signal in the channel concerned. This is done, for example in block B (n), by using the signal J from the join circuit 64 in the next channel "below", B (n+1), which will not be in its set condition if that channel does not contain data associated with the same object.

In respect of block B (n) the signal $\overline{E}$ is fed through gate 65 and OR gate 76. It is then combined together with a join signal J from the join circuit 64 in the block B (n+1) with a signal R ("reject") from a bistable circuit 73 in an OR gate 74 to feed an invertor 75 and generate the output signal D ("detect"). The signal D indicates valid parameters representative of the detected feature are available at the outputs of the processing block concerned, namely B (n). This data may either be fed to a printing means and printed out, or classified by further analysis, and then an appropriate counter is incremented.

The bistable circuit 73 furnishing the reject signal R may be set to reject objects which fail any of a number of tests. Such tests may be effected by feeding in test result signals such as T1, T2, T3 through OR circuit 77 to the bistable circuit 73. Such test signals may represent, for example, determination of whether the contents of the counters 63 in adjacent channels differ by more than a given amount, determination of whether the length of the object lies within a given range, a check for excessive indentations in the object.

It is to be noted that in Figures 5 and 6 some lines represent a single conductor carrying a single logical signal (nought or one) whereas others, for example those conveying signals A, W, L and the output from the counter 63, represent more than one conductor carrying a binary representation of a number.

Appropriate circuits would be included for resetting the counter and bistable circuits and for controlling the timing of the operations. These are conventional and are omitted for simplicity.

In the foregoing description with reference to the drawings, the spot areas have been dis-

closed as preferably adjacent to each other, that is contiguous or overlapping, so that collectively they form an elongate area of narrow width. It will be understood, however, that in some cases the spot area could be offset from each other in the direction in which relative movement takes place between the spot areas and the object during scanning. Thus they may be arranged in a rectilinear row, the length of which is oblique to the direction of relative movement between the row as a whole and the object during scanning. Alternatively the spot areas may be staggered on opposite sides of a reference line defining a row and extending at right angles to the direction of relative movement between the spot areas collectively and the object during scanning. In both cases the spot areas need not necessarily be contiguous or overlapping with each other. When, however, scanning takes place the tracks along which the spot areas scan would be contiguous or overlap laterally with each other.

The radiation which is utilised to stimulate the transducer elements need not necessarily be a light source furnishing radiation to the visible part of the spectrum. The source may be a source of non-visible radiation, for example infra-red radiant energy.

Again, instead of providing prisms 46, 47 and lenses 48, 49 for the automatic focusing system illustrated in Figure 4, convex and concave lenses could be provided in front of the slots S1 and S2 respectively and the signals then developed in the photomultipliers P17 and P18 would then be fed to the inputs of frequency selective amplifiers 57 and 58 to provide for automatic focusing.

Instead of utilising beam splitting prisms such as 46 and 47 as shown in Figure 4, an element of birefringent material may be introduced into the optical path of the image forming system. Conveniently such element may be incorporated in the eye piece of the microscope at an intermediate image position therein.

The photomultipliers P20, P21 would be mounted to receive light through light pipes (not shown) from apertures E20, E21 in the same image 29 as the apertures E1 to E16.

Associated with one of the elements P20 would be an optical filter for polarising the light rays incident at the aperture E20 in one direction, and other optical filter element would be provided in association with the element P21 to polarise, in a direction at right angles to that aforesaid, the rays incident at aperture E21. The filters would be placed in front of apertures E20, E21. This is because "twisting" of the planes of polarisation to an unpredictable degree may take place in passage of the light along the light pipe leading from the apertures E20, E21 to the transducer elements P20, P21 respectively.

The effect of the birefringent element is to produce optical paths of different lengths for the differently polarised rays incident at E20 and E21 so that the images formed thereat are defocused and transmitted to P20, P21 respectively in opposite senses.

The images incident at E1 to E16 will also be formed by rays which have transversed the birefringent element but not any polarisation filter and will accordingly consist of two superposed oppositely defocused images. However, the resultant images transmitted to P1 to P16 will still be adequately sharp.

To avoid defocusing of images incident at E1 to E16, a further refinement is illustrated in Figure 5. The element of birefringent material shown therein comprises a parallel sided disc including a portion 80 formed of two layers 81 and 82 of birefringent material, the first having its optic axis arranged in the direction of the arrow 83 and the second with its optic axis arrangement in the direction of the arrow 84 at right angles to the arrow 83. This element would, as before, be incorporated in the optical path at an intermediate image position, e.g. in the microscope eye piece.

Rays passing to the apertures E1 to E16 (from the frame area 16 and passing through an area in the birefringent element represented diagrammatically by the boundary 16*a*) are not subjected to any net birefringent effect, the thickness of the two layers 81 and 82 being equal to each other.

The element includes a further portion 85 which may be integral with the portion 82 and which is of segmental form and consists of a single layer of the birefringent material of the same thickness as the combined layers 81 and 82 and having its optic axis presented in the direction of the arrow 86.

Rays passing to apertures E20 and E21 traverse the portion 85 while rays passing to apertures E1 to E16 traverse the portion 80 (passing through the frame area 16*a*).

Since the portion 80 does not produce any net birefringent effect there is no defocusing of the images incident at E1 to E16.

In both the arrangements described signals produced from the transducer elements P20 and P21 are, as before, analysed and a control signal derived to control operation of a motor for automatic focusing adjustment of the microscope.

WHAT I CLAIM IS: —

1. A method of examining an object to provide data as to an optically presented characteristic thereof comprising the steps of establishing incidence of rays of radiant energy from at least three spot areas on the object on respective transducer elements responsive to said rays to produce primary electrical signals, effecting simultaneous relative movement in a first direction between said spot areas and said object in a manner such that said spot areas scan parallel adjacent tracks on said

object collectively forming a scanning band, said rays being modulated by visible boundaries on said object between respective areas thereof, and subjecting said primary signals to analysis to determine therefrom dimensions of said respective areas longitudinally of said tracks, and to determine whether said respective areas extend into adjacent ones of said tracks.

2. A method according to claim 1 wherein said spot areas are situated adjacent to each other in a row, and said relative movement in said first direction is transverse to said row.

3. A method according to either of claims 1 and 2 further comprising the steps of repeating said simultaneous relative movement in said first direction between said rays and said object, and additionally effecting relative movement between said object and said rays in a second direction transverse to said first direction and through a distance such that the scanning bands of respective successive cycles are positioned sufficiently closely to each other to be at least contiguous with each other along adjacent lateral boundaries of said bands.

4. A method according to claim 3 wherein successive scanning bands overlap laterally with each other.

5. A method according to any one of the preceding claims further comprising the steps of establishing incidence of optically controllable rays from an area on the object, which area is larger than said spot areas collectively, on a further transducer element responsive to said rays to produce an electrical reference signal, and applying said reference signal in analysis of said primary signals to compensate for variables affecting the amplitudes of said primary signals in a generally like manner.

6. A method according to any one of the preceding claims further comprising the steps of establishing said incidence of said rays on said respective transducer elements through the intermediary of adjustable focusing means establishing incidence of radiation passing through said adjustable focusing means on respective focusing control transducer elements through defocusing means providing defocusing in opposite senses to predetermined extents from a properly focused state to produce focusing control electrical signals at said focusing control transducer elements, analysing said focusing control electrical signals to derive a parameter representative of departure, if any, from said predetermined extent of defocusing, and controlling said adjustable focusing means with reference to said parameter properly to focus said rays on the first said transducer elements.

7. Apparatus for the examination of an object to provide data as to an optically presented characteristic thereof, comprising means for providing a source of radiant energy for illuminating said object, transducer means including at least three transducer elements responsive to radiation from said source to produce respective primary electrical signals, scanning means including firstly optical means for establishing incidence on said transducer elements of rays of said radiation from respective spot areas on said object, and means for causing said spot areas to travel relatively to said object concurrently along adjacent parallel scanning tracks collectively forming a scanning band, said rays being modulated by visible boundaries on said object between respective areas thereof, and electric circuit means for analysing said primary signals to determine therefrom data as to dimensions of said respective areas longitudinally of said tracks and whether said respective areas extend into adjacent ones of said tracks.

8. Apparatus according to claim 7 wherein said scanning means includes means which define a plurality of apertures through which said rays are admitted to said transducer elements respectively, said optical means includes means for forming an image of said scanning band to be incident on said aperture, and said means for causing said spot areas to travel relatively to said object comprises means for producing movement of said image across said apertures in a direction longitudinally of said scanning band.

9. Apparatus according to claim 8 wherein said apertures are positioned relatively to each other to form a row, and said means for causing said spot areas to travel relatively to said object establishes movement of said image relatively to said apertures in a direction transverse to the length of said row.

10. Apparatus according to claim 9 wherein said means for causing said spot areas to travel relatively to said object comprises a movable ray deflecting element.

11. Apparatus according to claim 10 wherein means are provided for mounting said ray deflecting element for rotation about an axis, motor means are provided operatively connected with said ray deflecting element to rotate same unidirectionally, and said ray deflecting element has a plurality of reflecting facets having normals which are spaced apart angularly at equal intervals about said axis to provide for incidence at said apertures of a succession of moving images of said scanning band.

12. Apparatus according to any one of claims 7 to 11 further including means for effecting relative movement between said spot areas collectively on the one hand and said object on the other hand in a direction transverse to said scanning tracks.

13. Apparatus according to claim 12 wherein said means for effecting said relative movement in said transverse direction operates to provide movement in this direction equal to, or less than, the width of the preceding scanning band, whereby successive scanning bands

are contiguous or overlap with each other along their lateral boundaries.

14. Apparatus according to claim 7 or any one of claims 8 to 13 as appendant thereto wherein said transducer means includes a reference signal transducer element responsive to said radiation to produce a reference electrical signal, said optical means establishes incidence of rays from said object on said reference signal transducer element from an area on said object larger than said spot areas collectively, said circuit means includes means responsive to said reference signals to compensate for at least one variable affecting the amplitudes of said primary electrical signal in a generally like manner.

15. Apparatus according to claim 14 wherein said circuit means includes means for amplifying said primary electrical signals, automatic gain control means, and means for feeding a gain control signal derived from said reference signal to said gain control means to control setting of same as a function of the intensity of illumination over the area of said object from which rays are incident on said reference transducer element.

16. Apparatus according to any one of claims 7 to 15 further comprising adjustable focusing means for focusing said rays on said respective transducer elements, focusing control transducer elements, optical defocusing means interposed in the path of rays from said area to said focusing control transducer elements respectively and providing for a predetermined degree of defocusing in opposite senses with respect to a properly focused condition, focusing control circuit means operatively connected to said focusing control transducer elements and providing an output signal representative of departure, if any, from said predetermined degree of defocusing, and actuating means for operating said adjustable focusing means in response to said output signal to set said adjustable focusing means in a condition properly to focus said image.

17. Apparatus according to claim 16 wherein the defocusing means includes an element of birefringent material through which rays pass to said focusing control transducer elements, means being provided to polarise in transverse directions respective rays passing to said elements.

18. Apparatus according to claim 17 wherein said focusing control transducer elements and said transducer elements receiving radiation from said spot areas are situated in a common image plane, the element of birefringent material comprising a portion traversed by rays passing to the transducer elements from the spot areas and which is composed of layers of said material arranged with their optic axes substantially at right angles to each other to compensate each other in respect of the birefringent effect, and a portion traversed by rays passing to said focusing control transducer elements and designedly providing a birefringent effect.

19. Apparatus according to any one of claims 7 to 18 wherein the optical means includes means for forming a magnified optical image of the object incident on the transducer elements.

20. A method of examining an object substantially as herein described with reference to and as illustrated by Figures 1 to 3 of the accompanying drawings.

21. Apparatus for examination of an object substantially as herein described with reference to and as illustrated by Figures 2 and 3 of the accompanying drawings.

22. Apparatus according to claim 21 including a focusing control means substantially as herein described with reference to and as illustrated by Figure 4 or Figure 5 of the accompanying drawings.

23. Apparatus according to claim 21 including means for analysing the primary signals substantially as herein described with reference to and as illustrated by Figures 6 and 7 of the accompanying drawings.

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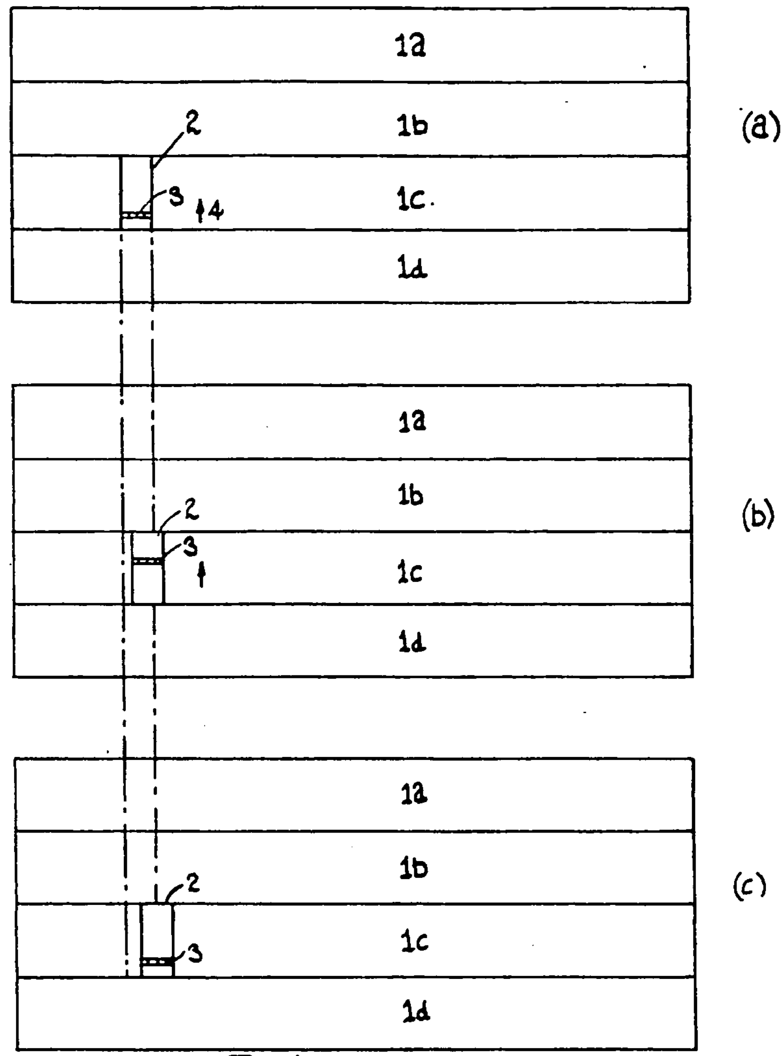
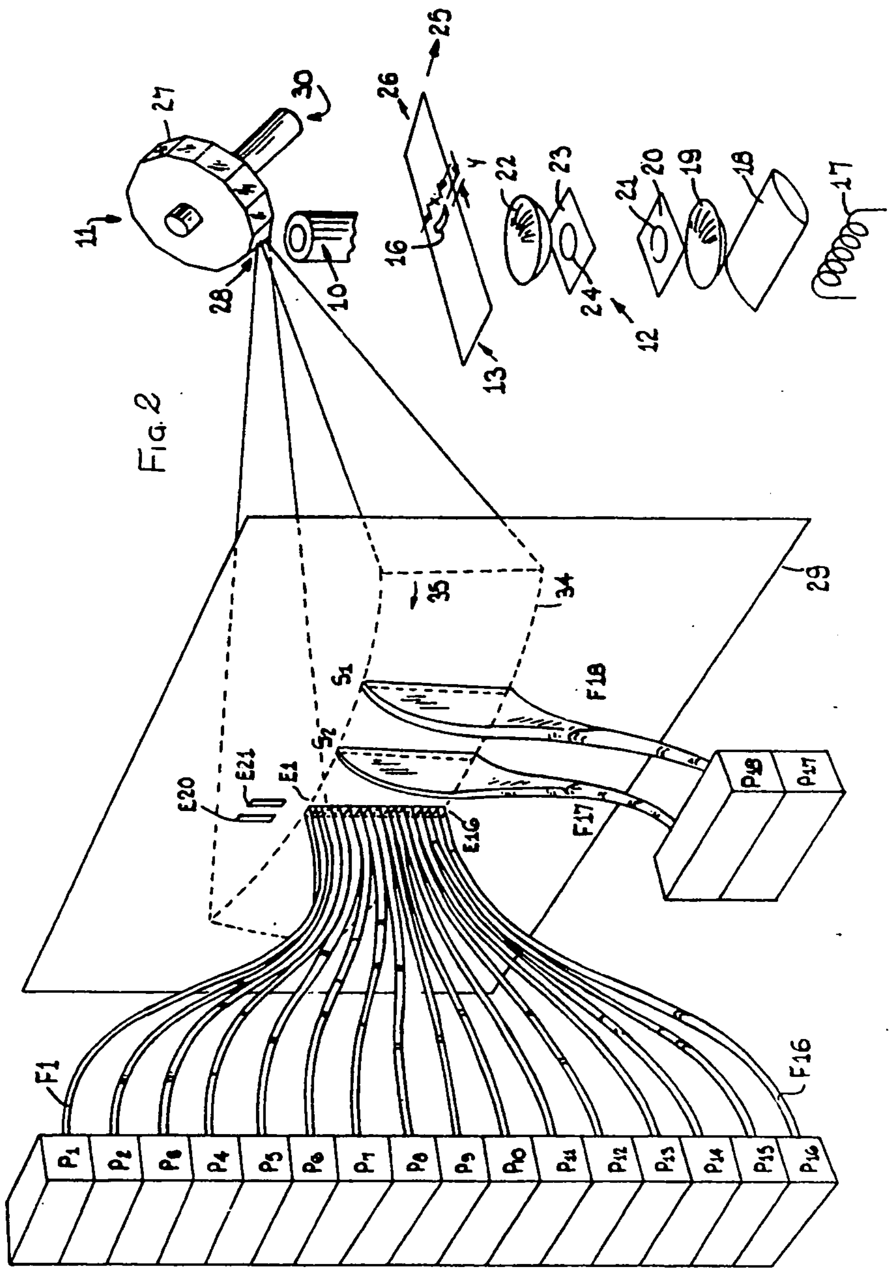



FIG. 1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Y
S1
S2
E1
E16
E20
E21
F1
F16
F17
F18
P1
P2
P3
P4
P5
P6
P7
P8
P9
P10
P11
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P16
P17
P18

Fig. 2

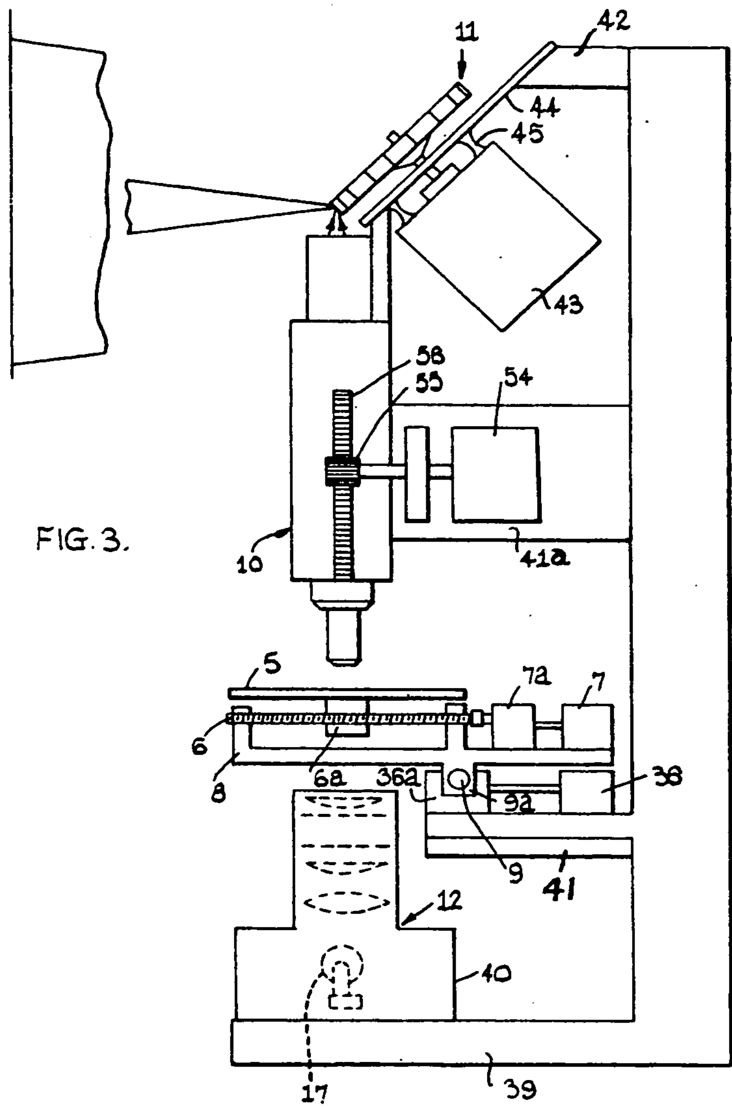


FIG. 3.

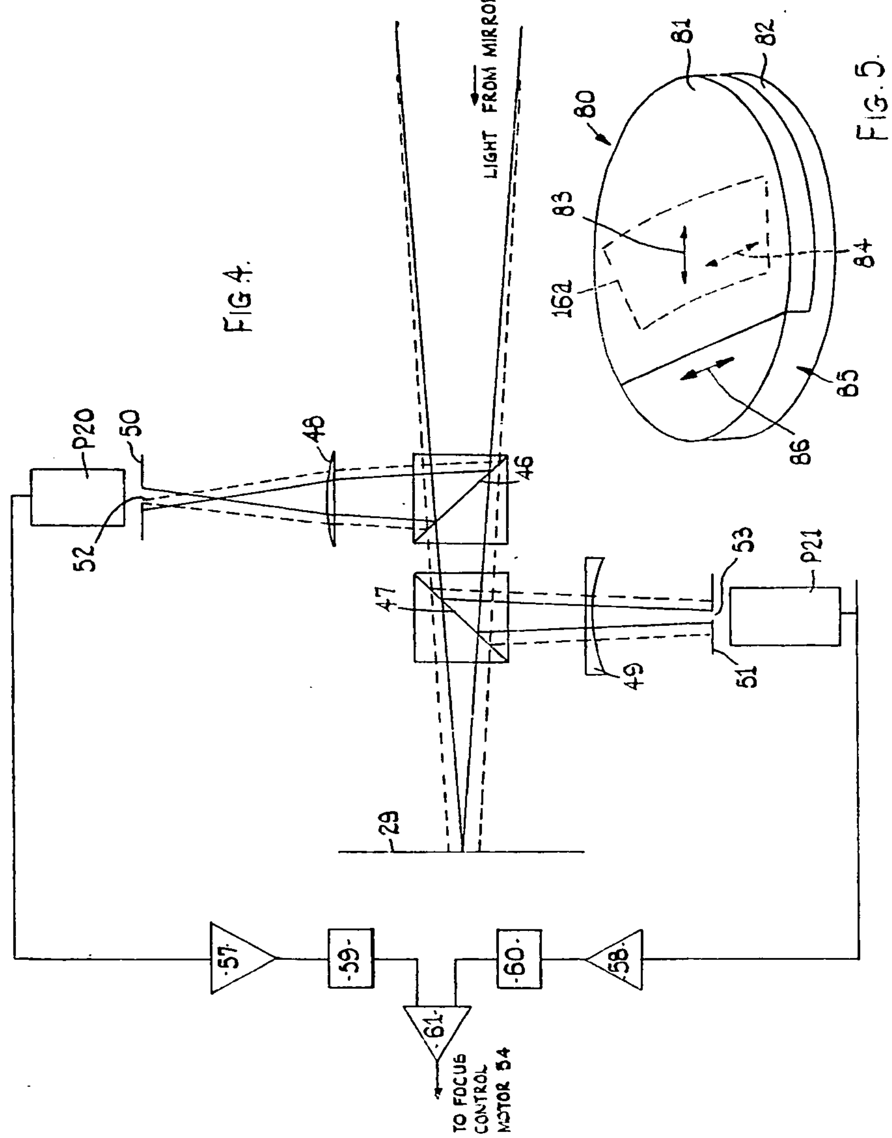
LIGHT FROM MIRROR DRUM.
P20
50
48
46
52
47
53
P21
49
51
29
57
59
60
58
61
TO FOCUS CONTROL MOTOR 54
80
81
82
83
84
162
85
86

FIG.4.

FIG.5.

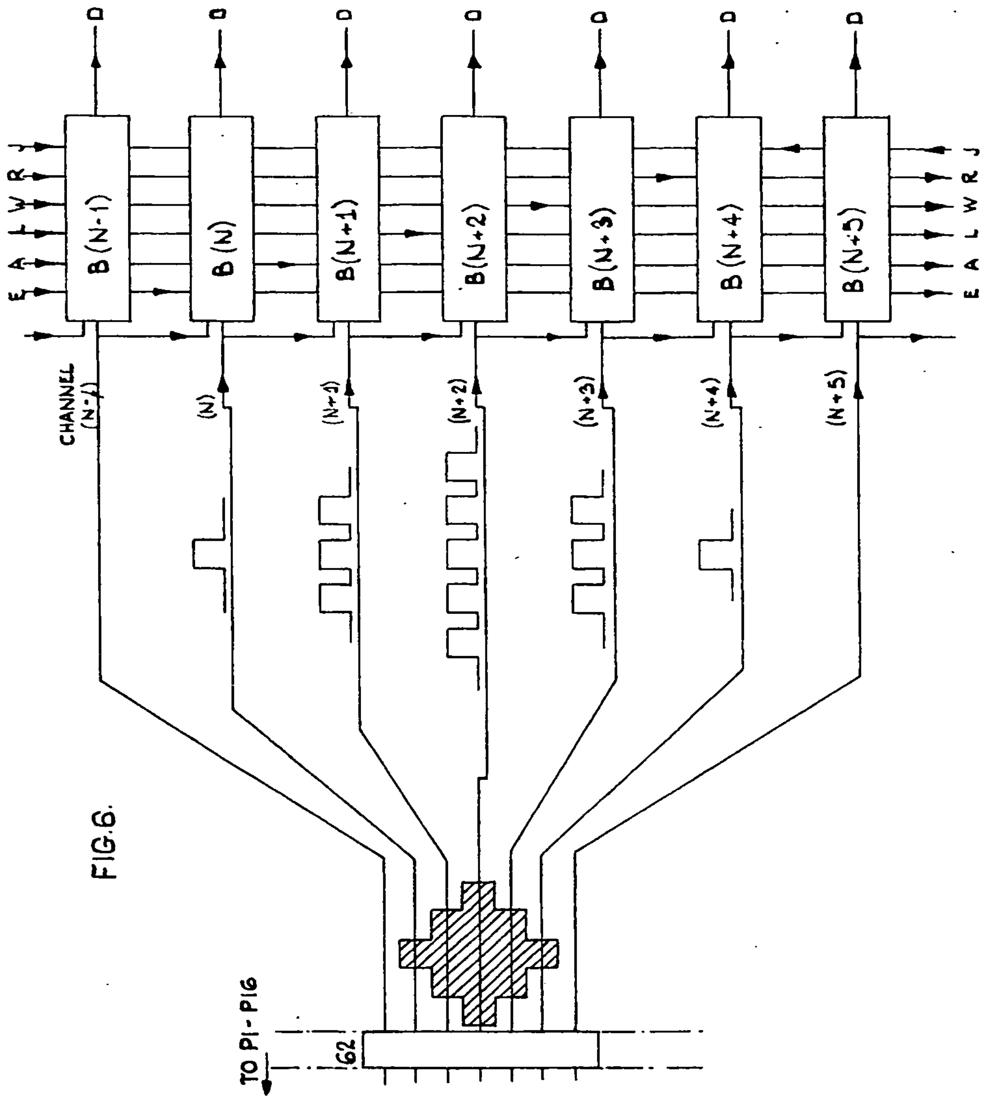
D
B (N-1)
B (N)
B (N+1)
B (N+2)
B (N+3)
B (N+4)
B (N+5)
E A L W R J
CHANNEL (N-1)
(N)
(N+1)
(N+2)
(N+3)
(N+4)
(N+5)
TO PI - PIG
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FIG.6.

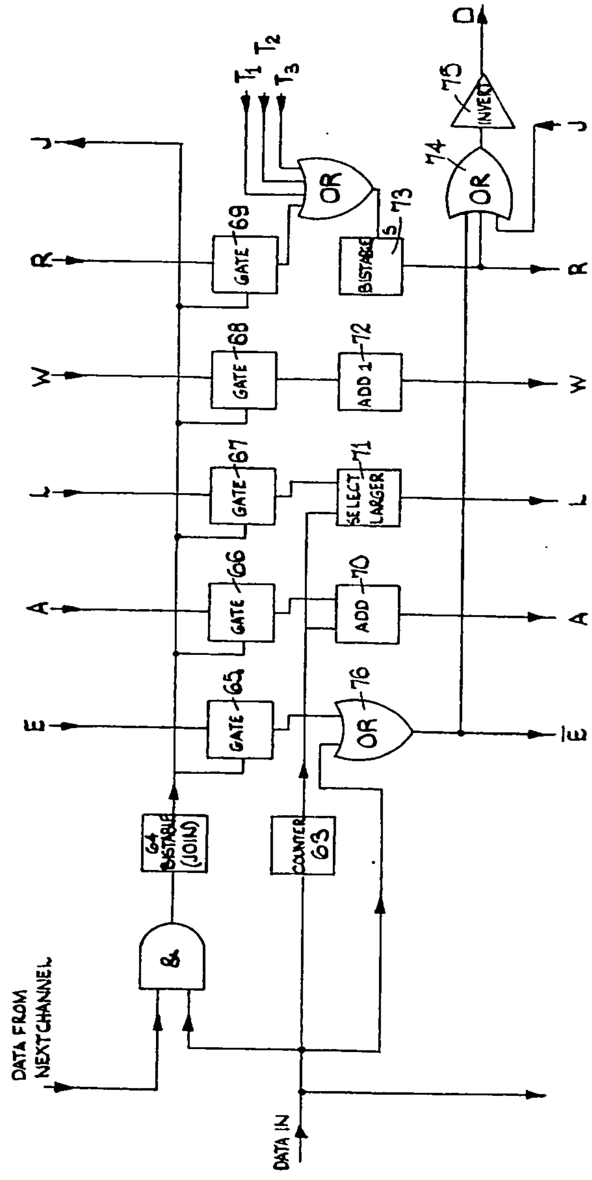
DATA FROM NEXTCHANNEL
DATA IN
&
64 BISTABLE (JOIN)
COUNTER 63
E
A
L
W
R
J
GATE 65
GATE 66
GATE 67
GATE 68
GATE 69
OR 76
ADD 70
SELECT LARGER 71
ADD 1 72
BISTABLE 73
OR
OR 74
INVERT 75
D
$T_1$
$T_2$
$T_3$
$\bar{E}$

FIG 7